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Improvements to cheap loudspeakers

H.D. Harwood, B.Sc.
R. Mathews

Research Department, Engineering Division
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Summary

The sound quality of portable domestic audio equipment is limited mainly by the loudspeaker and cabinet. An investigation has been made to determine whether, at negligible extra cost, worthwhile improvements can be made. It is concluded that in some cases, small but worthwhile improvements are possible.

Issued under the authority of

G.D. Monteath

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

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1. Introduction

It has long been apparent that the sound quality of even the more expensive portable radios available often leaves a lot to be desired; this is also true of portable cassette recorders and combinations of the two. The electronics of such devices, particularly radios employing a v.h.f.-waveband should be capable of giving reasonably good sound quality. It therefore seems likely that the deficiency lies mainly in the loudspeaker and its associated cabinet. With this in mind it was decided to investigate simple methods of improving the sound quality of such loudspeakers either by modifications to the unit or cabinet design. It must be borne in mind, however, that low cost is of prime importance since the typical cost of the type of loudspeaker unit in question is in the order of two to three pounds.

2. The choice of units

The range of loudspeaker units available is enormous and it was not felt that a full scale investigation was justified. The experiments were therefore limited to one example of each of the two commonly used types, that is circular and elliptical (wide frequency range) units.

The circular loudspeaker unit chosen was of British manufacture, being 165 mm overall diameter and possessing an auxiliary high frequency cone. The elliptical unit was of Swedish manufacture, being 152 mm x 102 mm overall. It was felt that these two units were a fair representation of what is commonly used in the more expensive portable equipment. In both cases the cone and surround were of paper pulp, the surrounds being lightly doped with a damping material.

Six samples of each unit were obtained in order to make some assessment of repeatability. It was decided to mount the units in cabinets of similar size to a large portable radio. Accordingly, four cabinets 305 mm x 203 mm x 102 mm internal dimensions were manufactured from 9 mm plywood, two cabinets for each type of unit. In each case the unit was mounted centrally on the inside of the front face.

3. Methods of test

The test methods were as follows:—

(a) Objective. Steady state axial responses were taken at 1·5 m for the various conditions.

(b) Subjective. To assist in the subjective assessment of various modifications to the units, recordings of programme and pink noise were made in the free field room on the loudspeaker axis using a Brüel & Kjaer 12·7 mm microphone.

These recordings could then be replayed over a monitoring loudspeaker and compared for sound quality. In this way it was possible to determine the change in sound quality due to modifications on the same unit, and separate units each with its own modification were not necessary.

Further, back reference to any particular stage was possible.

4. Tests

Loudspeaker Type A; (the Swedish elliptical unit).

1. Objective Tests

Fig. 1 shows the free-field axial response/frequency characteristic of a typical unmodified unit in a bare cabinet. The effect on axial response/frequency characteristic of mounting the same unit in a cabinet lined on the sides and rear with 12·7 mm polyurethane foam is shown in Fig. 2. The irregularities in the 1 to 3 kHz region are seen to have been largely removed by this modification. Fig. 3 shows the spread in characteristics from the six specimens when mounted in the treated cabinet. Fig. 4 shows the axial response of a typical unit in a treated cabinet when the whole cone had been coated with one layer of Plastiflex type 1200. Note the decrease in sensitivity and corresponding extension of bass response due to the extra mass. Finally Fig. 5 shows the effect of applying Plastiflex to the surround only of a unit which is otherwise unmodified.

2. Subjective Tests

The sound quality corresponding to Fig. 1 was 'boxy' and unpleasantly coloured, however, going to Fig. 2 the addition of the foam to remove resonances within the cabinet did reduce the 'boxy' nature of the sound quality. Fig. 4 represented a very small improvement in sound quality and it was felt that the overall loss in sensitivity was unacceptable. Finally Fig. 5 gave an equally disappointing sound quality. There was only a very small reduction in the level of colorations and a slight increase in the 'hardness' of the sound quality.

Loudspeaker Type B (British circular unit).

1. Objective Tests

Fig. 6 shows the free-field axis response/frequency characteristic of a typical unmodified unit in a bare cabinet. The uneven response between 1 and 5 kHz is again due to air modes in the cabinet.

Fig. 7 is a typical unit in a cabinet with acoustic damping applied. Note that the high-Q resonances between 1 and 5 kHz have been substantially removed. The general irregularity of response above 5 kHz is possibly due to air resonances within the auxiliary high frequency cone or within the material of the cone itself. The spread in characteristics of the six specimens when mounted in a damped cabinet is shown in Fig. 8.

As a first experiment the high frequency cone was removed from a typical unit; this was tried because the h.f. response was so irregular. The result can be seen in Fig. 9 and shows a falling h.f. response above 5 kHz of approximately 12 dB/Octave. This was considered to be quite unacceptable. Fig. 10 shows the result of doping the whole cone with one coat of Plastiflex. Apart from a slight decrease in overall sensitivity and correspondingly small improvement in bass response, there was no useful reduction in the level of irregularities or colorations.

It was then decided to try doping the surround only. Fig. 11 shows the result of two coats of Plastiflex applied to the surround. It can be seen that there is a remarkable improvement in the smoothness of the response between 400 Hz and 3·5 kHz. The cancellation at 4 kHz was not considered to be of too great importance, since past experience has shown such narrow dips to be relatively inaudible.

Finally, in an effort to improve the high frequency response, the auxiliary h.f. cone was lightly packed with cotton wool. It was hoped that this might damp out air modes within the cone. It was felt that these air modes might be the cause of the poor h.f. response since the physical depth of the cone was comparable to its diameter which in turn was comparable to the wavelengths at 4 kHz and above. The result can be seen in Fig. 12, and apart from a reduction in the dip at 4 kHz any improvement was insignificant.

2. Subjective Tests

The sound quality corresponding to Fig. 6 was particularly unpleasantly coloured, more so than the same condition for loudspeaker unit type A. The addition of air damping to the cabinet gave the result shown in Fig. 7 and again furnished a useful improvement in sound quality. However, the sound quality corresponding to Fig. 11 was a substantial improvement and in fact was felt to be superior to that of the type A unit despite an inferior performance in the unmodified state.

5. Final subjective appraisal

It was decided that the results obtained warranted a formal subjective appraisal by a panel of experienced listeners. Two subjective comparisons were made of four conditions, namely:

1. an untreated elliptical unit in a bare cabinet,
2. an elliptical unit in a lined cabinet, the unit having extra damping applied to the surround,
3. an untreated circular unit in a bare cabinet,
4. a circular unit with damped surround in a lined cabinet.

In the first comparison the untreated elliptical unit in a bare cabinet was taken as the reference standard, and in the second test the treated circular unit in a lined cabinet was taken as the reference. Table 1 shows the results of these tests and may be summarised as follows. Both tests showed that contrary to what would be expected from the objective curves of response/frequency characteristics, the untreated elliptical unit was slightly preferred to the treated one. Although the difference is small both tests show this tendency so it is probably correct. The reason for this result is thought to lie in the fact that the untreated unit gave a rather hard sound quality which was accentuated by the changes.

In contrast the treated circular unit was preferred to the untreated to the extent of 0·9 grade of the CCIR grading and was therefore an obvious improvement; it was also preferred to the elliptical unit in either condition.

6. Conclusion

Two types of cheap commercially available loudspeaker unit were investigated to see if their performance could be usefully improved for a suitably low cost. The two types of loudspeaker unit examined gave a rather 'coloured' sound quality that was consistent with their methods of construction; in particular, a paper pulp cone of high stiffness and Q terminated by a stiff and relatively undamped surround. Attempts to improve the static response/frequency characteristic and reduce the level of audible colorations by treating the loudspeaker cone were unsuccessful. It would appear that due to the high stiffness and Q, the quantity of damping material necessary to bring about any useful reduction in irregularities of response would in turn cause an impractical reduction of the unit sensitivity due to the increased mass.

However, the application of extra damping to the surrounds of the two types of unit proved to be more successful, particularly in the case of the circular type B unit. The purpose of a surround is to provide mechanical support for the cone without influencing its operation. The surround must therefore provide the correct mechanical impedance termination between the moving cone and stationary loudspeaker frame. The application of damping material to the surround will reduce its Q and although the termination may still not be correct, its tendency to resonate will be reduced.

Finally, the application of air damping to the internal walls of the cabinets did improve the static response/frequency characteristics in both cases. However, it only provided a useful improvement in sound quality for the circular type B.

It may be concluded that all the above modifications are capable of giving useful improvements in sound quality, with one very important proviso. If an improvement is made to any one part of the audio spectrum, it may well give prominence of shortcomings elsewhere in the spectrum which were previously masked: this was particularly true in the case of the type A elliptical unit.

TABLE 1

CCIR Seven Point Grading Scale

+3	Much Better
+2	Better
+1	Slightly Better
0	Same
–1	Slightly Worse
–2	Worse
–3	Much Worse

	Type B Treated -v- Type A Bare		Type A Treated -v- Type A Bare		Type B Bare -v- Type A Bare		Type A Bare -v- Type A Bare	
	Speech	Music	Speech	Music	Speech	Music	Speech	Music
Mean	1·08	0·08	–0·45	–0·62	–0·2	–1·67	0	0
Standard Deviation	2·06	2·01	1·41	1·03	1·79	1·47	0	0
Standard Error	0·92	0·90	0·63	0·45	0·5	0·66	0	0
Mean Speech/ Music	+0·58		–0·54		–0·93		0	

	Type A Bare -v- Type B Treated		Type B Bare -v- Type B Treated		Type A Treated -v- Type B Treated		Type B Treated -v- Type B Treated	
	Speech	Music	Speech	Music	Speech	Music	Speech	Music
Mean	–0·63	–0·56	–1·22	–0·53	–1·31	–2·19	0	0
Standard Deviation	1·71	1·35	1·01	1·06	1·53	0·65	0	0
Standard Error	0·76	0·60	0·45	0·47	0·68	0·29	0	0
Mean Speech/ Music	–0·6		–0·88		–1·75		0	

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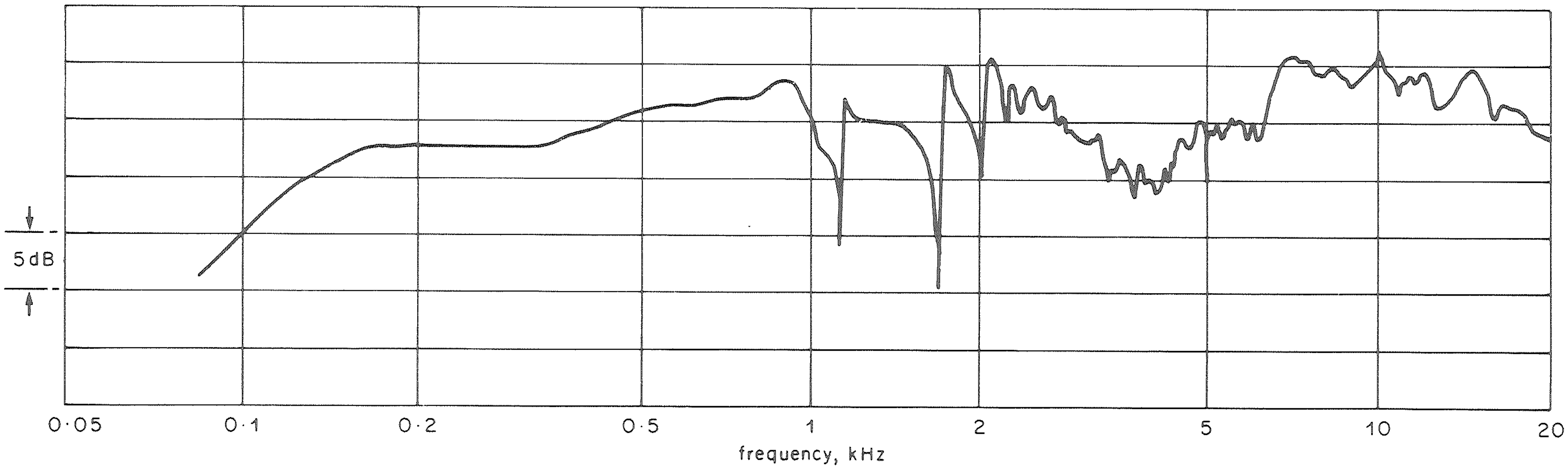

Fig. 1 - Type A unit unmodified in bare cabinet

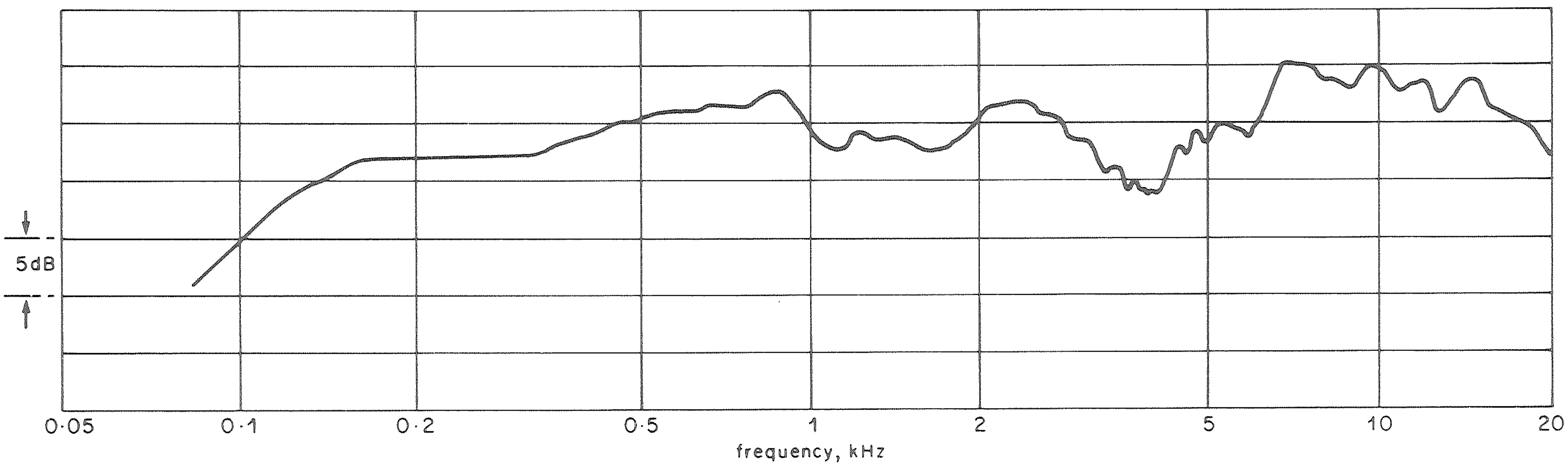

Fig. 2 - Type A unit unmodified in lined cabinet

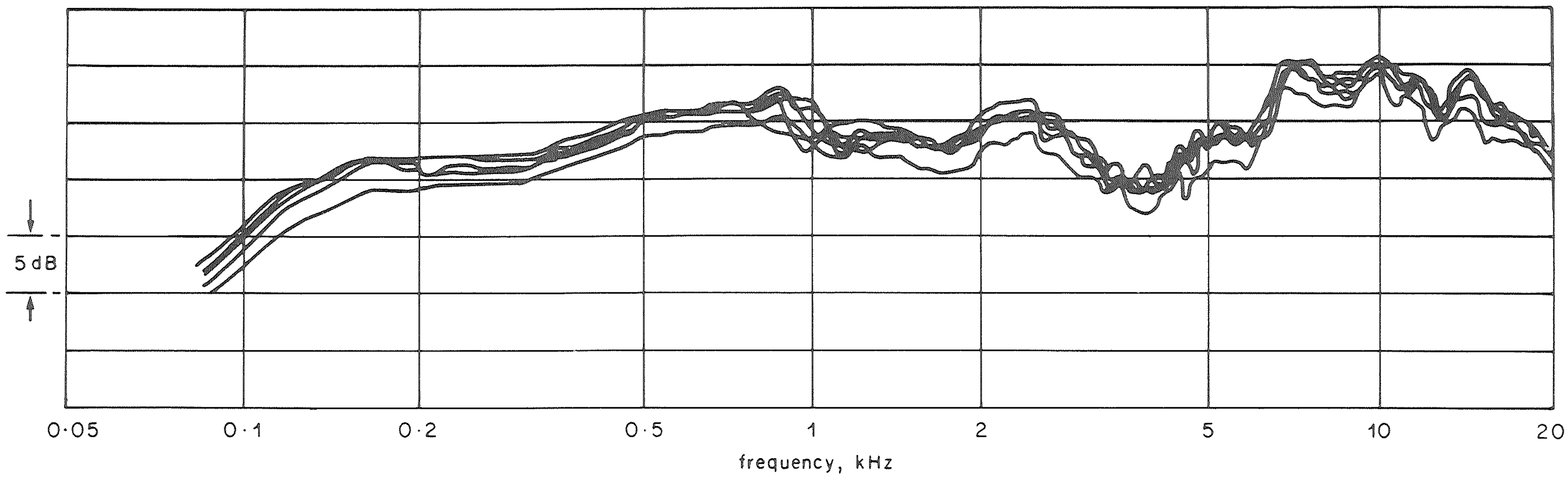

Fig. 3 - Spread in characteristics of unmodified Type A units in lined cabinet

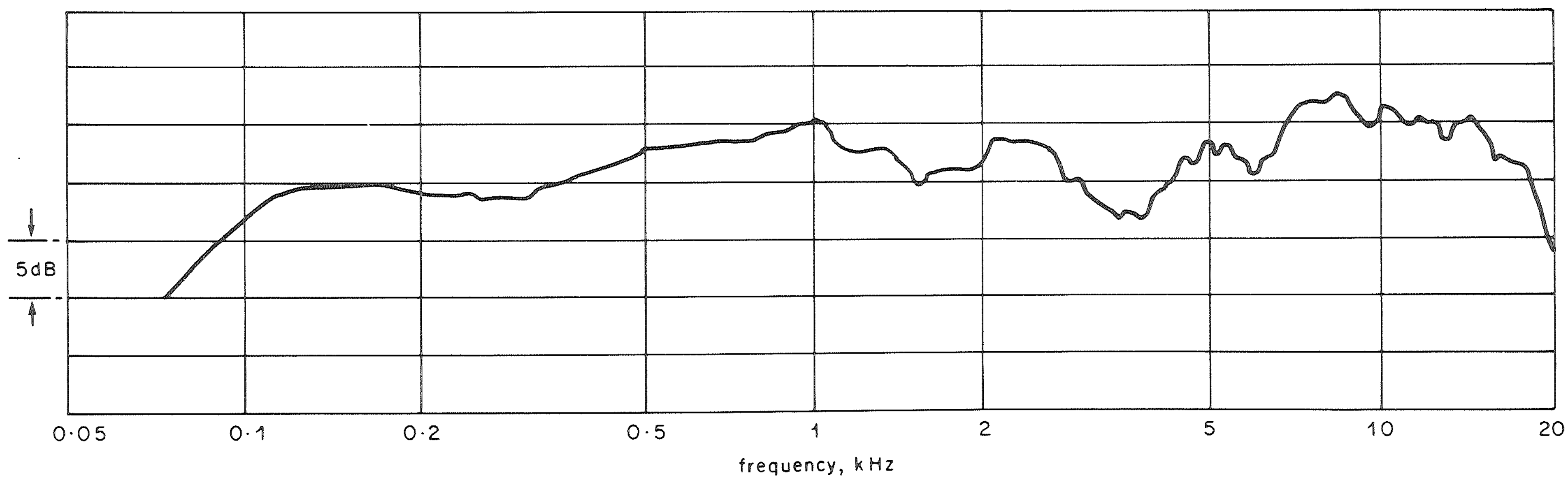

Fig. 4 - Type A unit with damped cone in lined cabinet

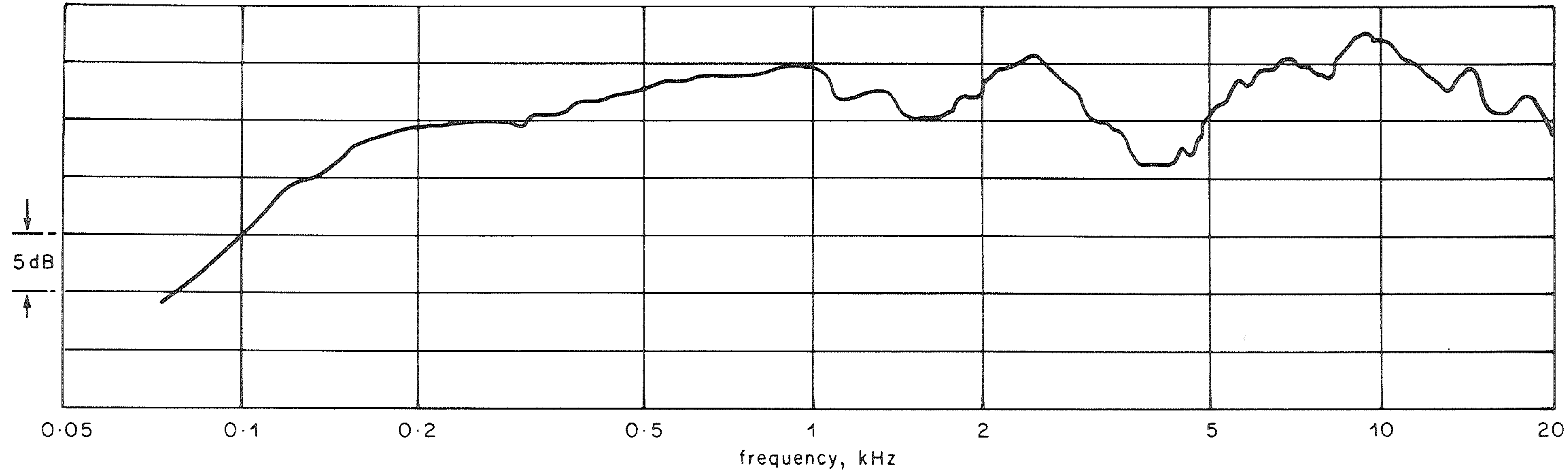

Fig. 5 - Type A unit with damped surround in lined cabinet

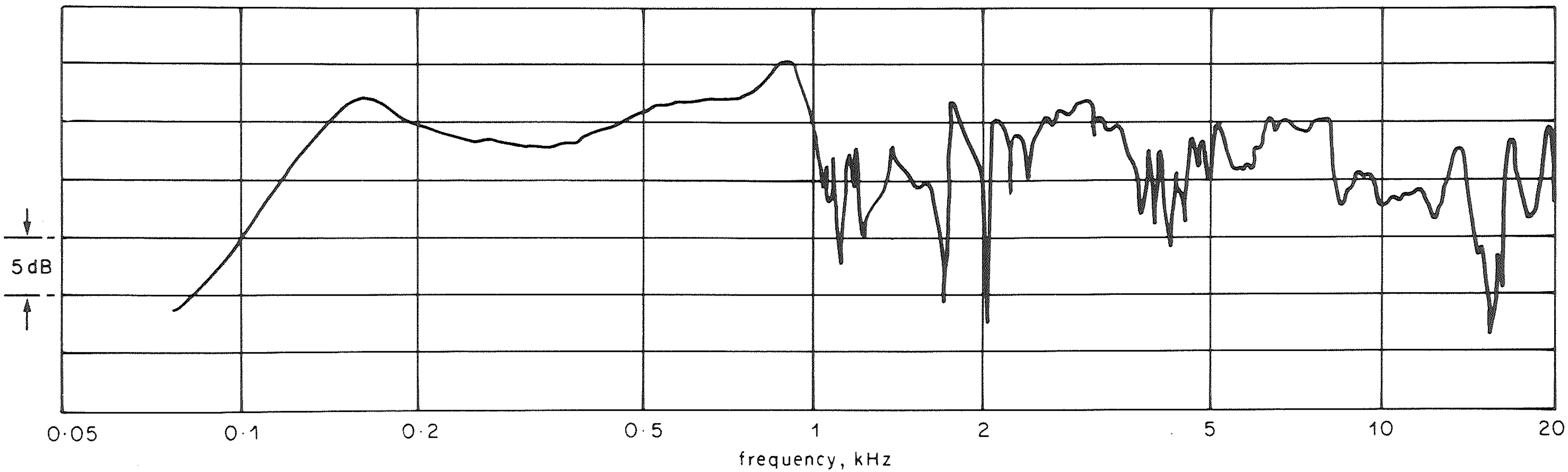

Fig. 6 - Type B unit unmodified in bare cabinet

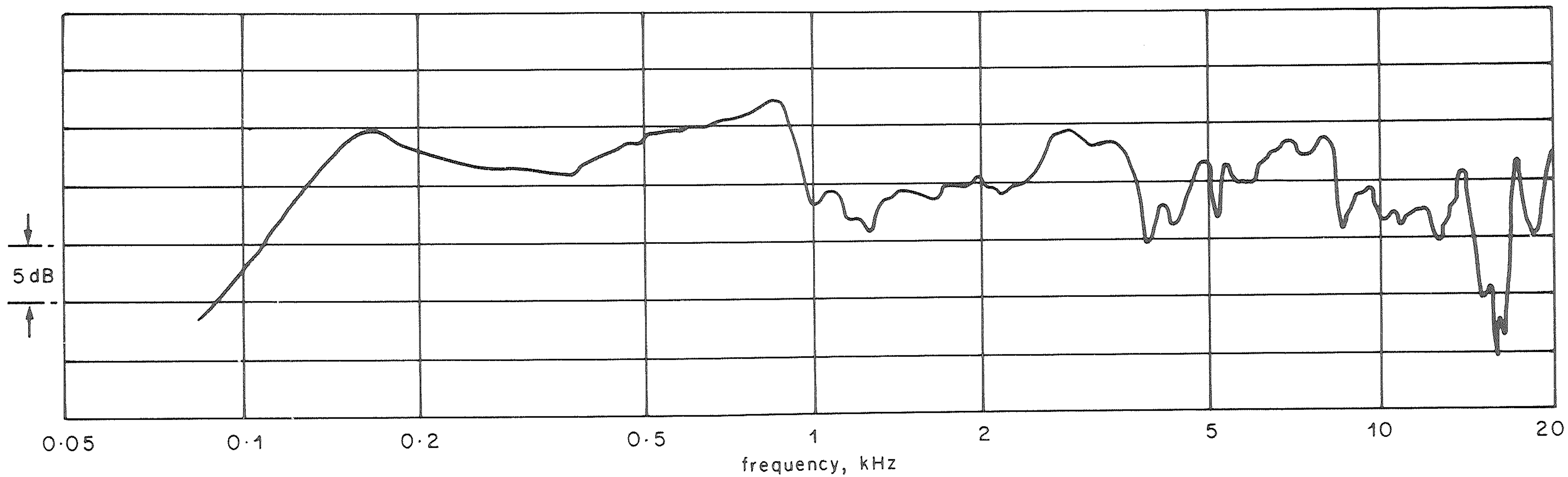

Fig. 7 - Type B unit unmodified in lined cabinet

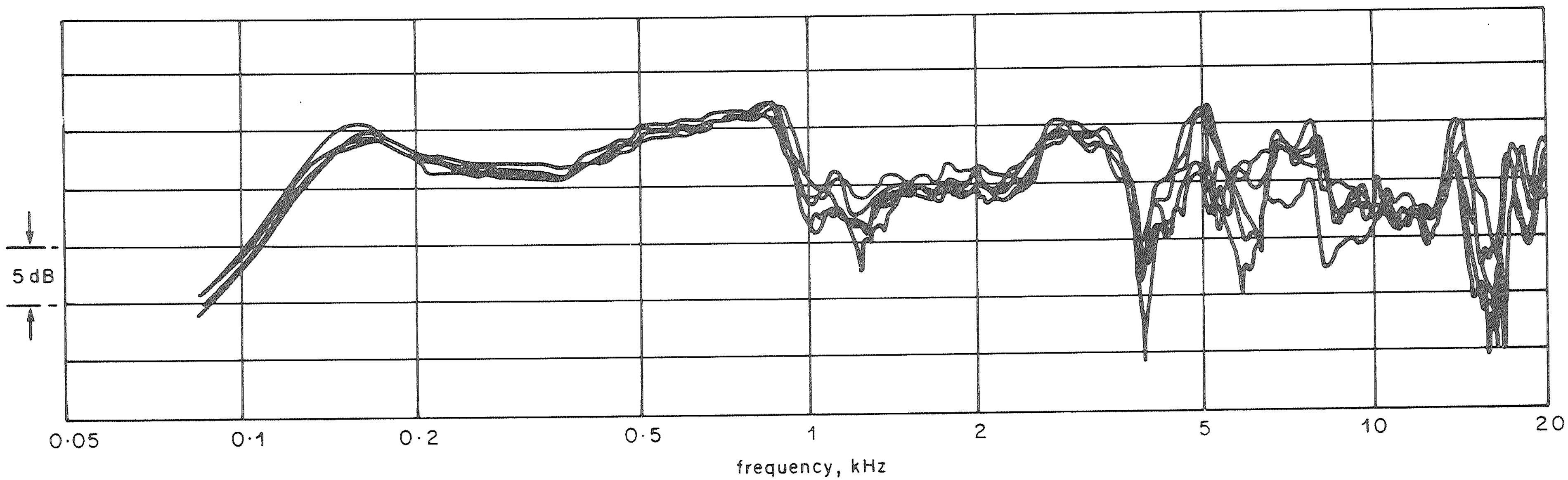

Fig. 8 - Spread in characteristics of unmodified Type B units in lined cabinets

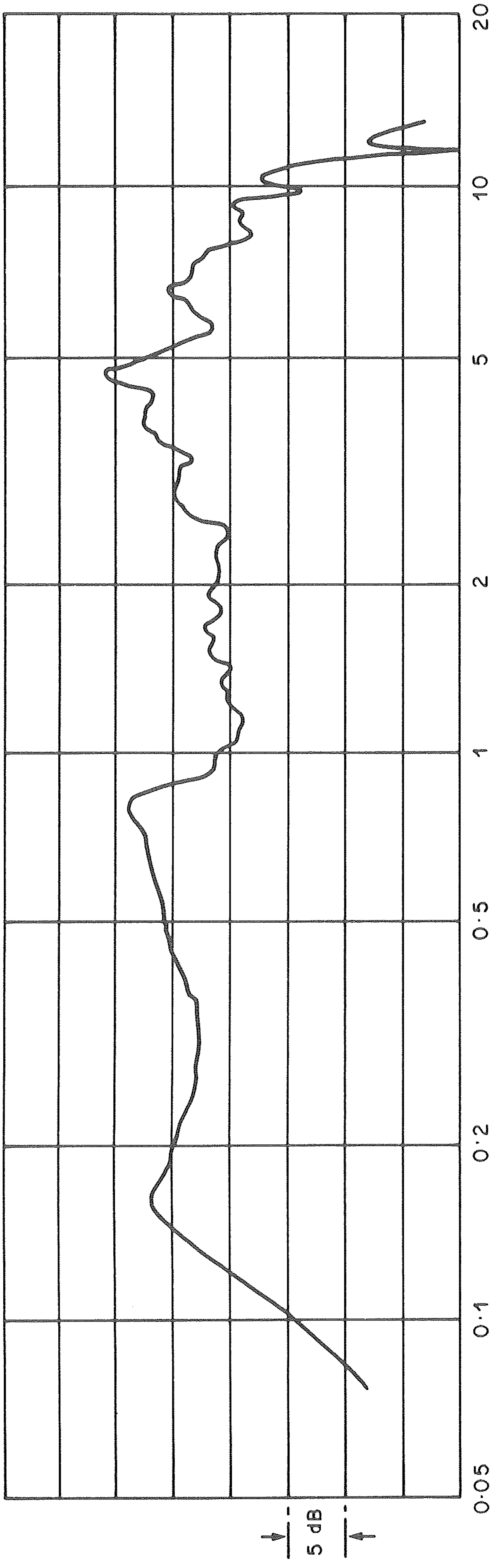

Fig. 9 - Type B unit with HF cone removed in lined cabinet

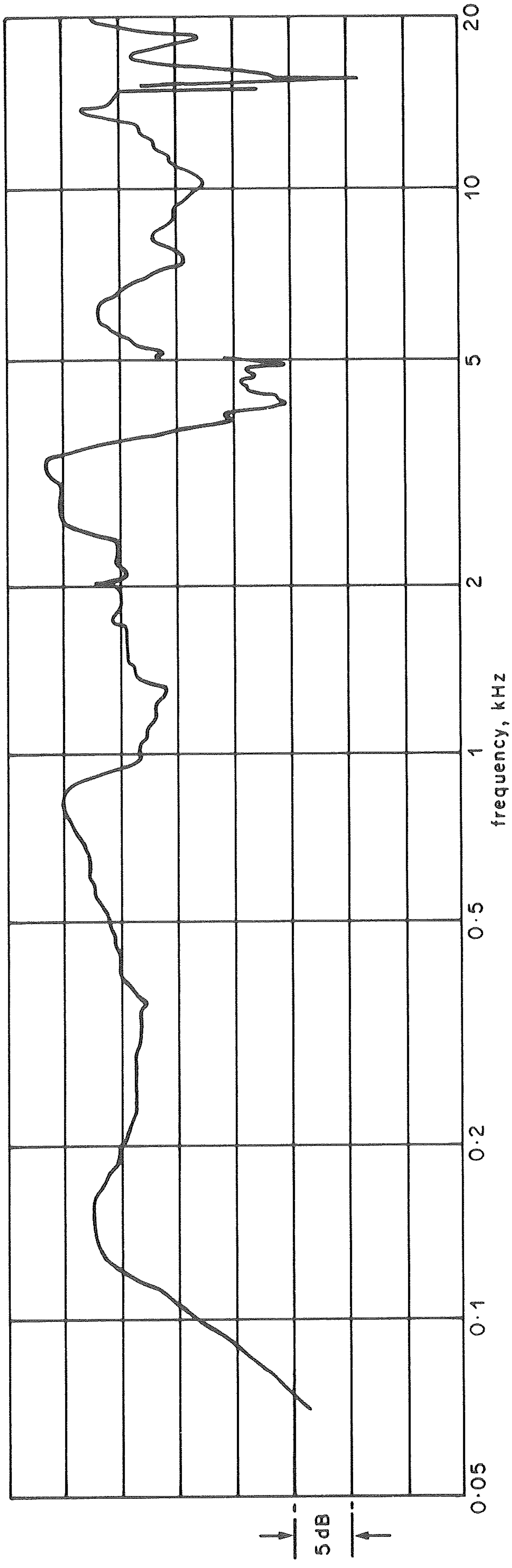

Fig. 10 - Type B unit with damped cone in lined cabinet

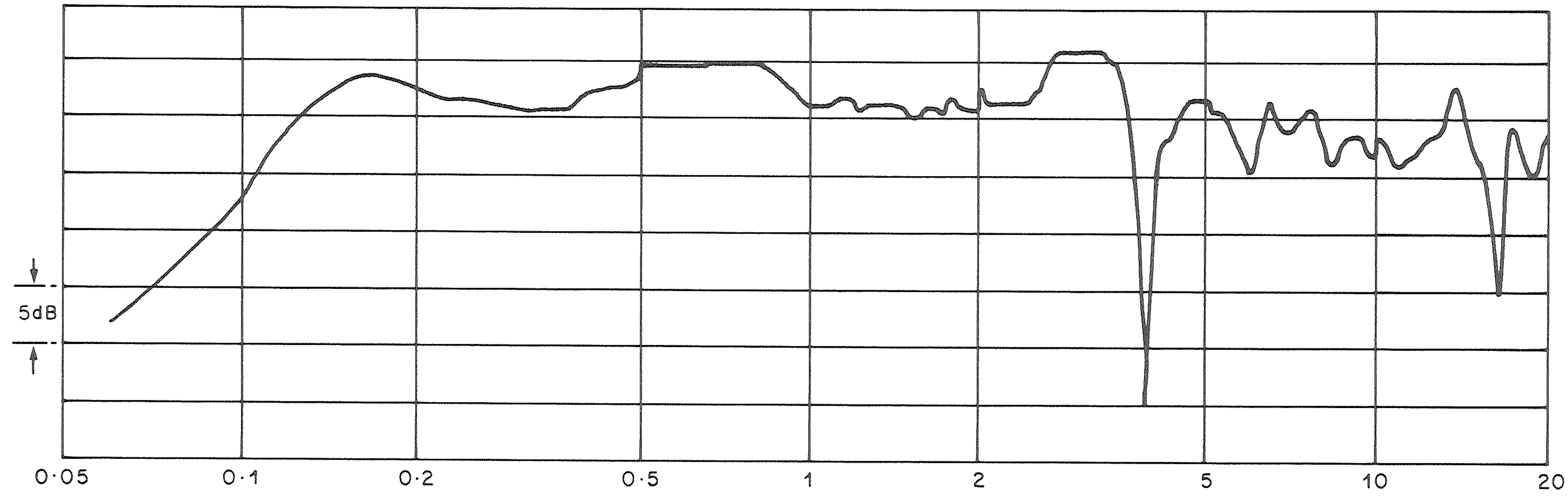

Fig. 11 - Type B unit with damped surround in lined cabinet

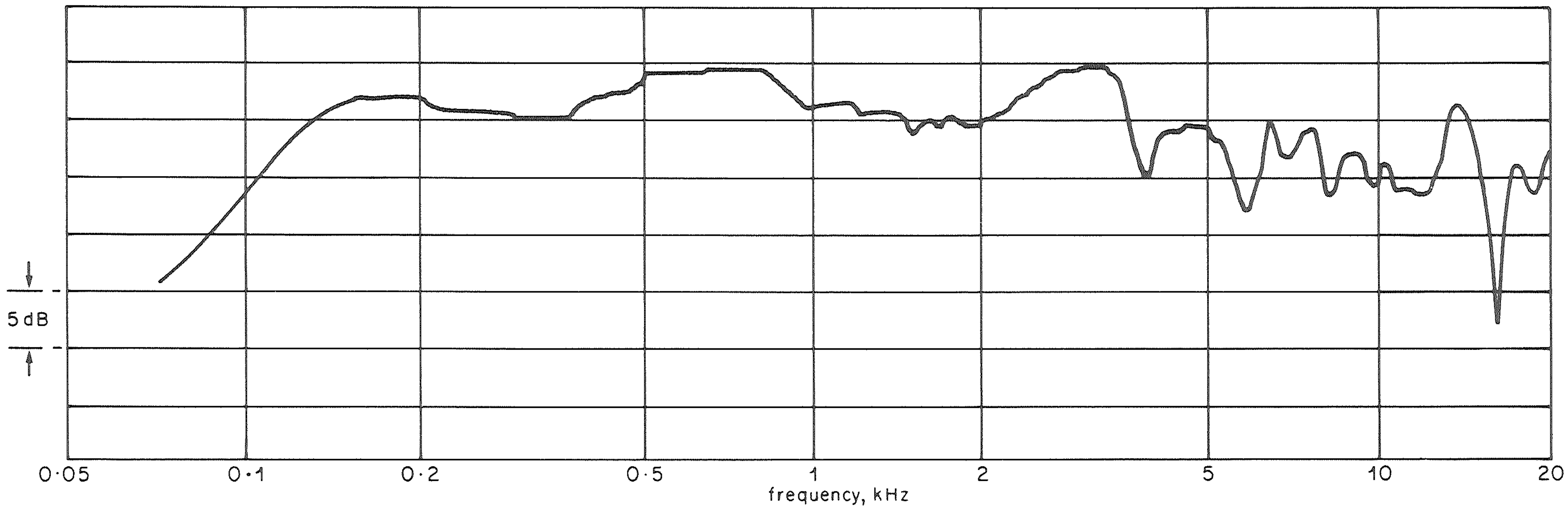

Fig. 12 - Type B unit with damped surround and HF cone packed with cotton wool in lined cabinet

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